FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

GREEN MANUFACTURING: AFRICA'S ALTERNATIVE FOR INDUSTRIAL DEVELOPMENT

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28TH FEBRUARY, 2024

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PREAMBLE

Bismillahir Rahmanir Raheem! All praise and gratifications go to almighty Allah (SWT) who has graciously made this day possible for me to stand before your Excellencies as my highly distinguished audience. May His super magnanimity to mankind through our beloved Prophet Muhammad (SAW) grant everyone here his/her desire. Inaugural lecture provides a forum for a Professor to speak to a gathering from within and outside university on his/her contribution to knowledge for advancement of man. May almighty Allah (SWT) guide me through; Amin.

The Vice Chancellor and Chairman of this gathering, Deputy Vice Chancellors, Registrar, Librarian, Bursar, other Principal Officers of the University, Deans, Directors, my Professor colleagues, members of Senate, Heads of Department, great students of FUT Minna, other members of this University community, invited guests, distinguished ladies and gentlemen; I welcome you all to this auspicious gathering of my inaugural lecture. The topic of the lecture is "Green Manufacturing: Africa's Alternative for Industrial Development". This topic was selected based on the state of industrial development of the African continent, the developed world, level of exploitation of non-renewable resources of earth with its attendant negative impacts and possible sources of renewable raw materials for sustained industrial activities.

1.0 INTRODUCTION

In order to make a smooth progression in this treatise, I hereby crave your kind indulgence to briefly explain the key terminologies in the title as regards usages in this lecture.

1.1 Green Manufacturing

Manufacturing is group of activities carried out in any industry that makes products from raw materials by use of manual labour/machinery for creation of tangibles, usually carried out systematically with division of labour. In limited sense it denotes fabrication and assembly of components to finished products on large scale (Richard *et al*, 2021). Heavy manufacturing plants produce aircraft, automobile, ship, chemical, electronic, furniture, clothing, petroleum products, steel e. t. c. An industry is made up of productive enterprises and organizations that produce/supply goods and services. In ever-changing/adapting world; common issues that affect industries are their operations, sustainability of raw material, waste management and environmental degradation (Richard *et al*, 2021); solution to which is green manufacturing.

Green manufacturing is renewal of production and establishment of environmentally-friendly operations within industrial field. Green technologies/practices are used to: reduce/remove release of pollutants in operations, reduce greenhouse gas emission, reduce/eliminate creation of waste and collect, reuse/recycle or compost wastes. Man has been consuming resources at alarming pace that is certainly not sustainable as earth that we inhabit cannot regenerate these materials at that rate. For comparison, from 1950 to 2005, worldwide metals production grew six fold, oil consumption eight fold and natural gas consumption 14-fold; all from non-renewable sources. So if we continue in same path our future generations will not have access to resources as we have now. Green manufacturing which refers to production processes that pollute less with less waste must be deployed to ease attendant adversities (Richard *et al*, 2021). Waste from manufacturing, products use and afterlife is responsible for environmental degradation. Minimizing resource use and environmental impact by greening of manufacture is vital and achievable by practices that influence product, process design and operational principles. These combined with manufacturing, planning and control to identify, quantify, manage waste and increase self-recovery capability of earth to maximize resource efficiency.

1.2 Needs for Green Manufacturing

Every human practice that has benefits also has adversaries on earth. With the ever increasing human population, exploitation of natural resources, proliferation in capacity to produce and increase sophistication in manufacturing to man's needs, sustainable development, mitigation against catastrophic destruction of mother earth and safety engineering are critical challenges which must be addressed. How issues manifest and how green manufacturing can reduce the adverse effects are of interest. 21st-century definition of sustainability goes far beyond these narrow parameters. Today, it refers to need to develop sustainable models needed for human and earth to survive. United Nations 1987 Report of World Commission on Environment and Development noted that sustainable development is meeting the needs of the present without compromising well-being of future generations (Bakari and Mohamed, 2017). In 2000 Earth Charter broadened the definition of sustainability to include idea of global society based on respect for nature, universal human right/justice and culture of peace (James *et al.* 2015). To attain these lofty goals man must review policies on the following:

- Environmental protection.
- Social responsibility.
- Economic practice.

These goals are not distinct from one another but are interwoven such that changes that affect one goal directly or indirectly affect others in varied depths. Old models of consumption and industrialization will not support world's growing population and needs. If man must have water, materials and natural resources to thrive; new approaches to living are needed. Thus, modifications must be made to practices to preserve water, materials and natural resources. This balances the system as resource exploitation/investment and orientation of technological development are harmonized such that current and future generations have potentials to meet needs/aspirations. Advancement has raised consumption of manufactured goods/services, living standard, concern for raw material sustainability and environment/social responsibility.

Population growth combined with developed society's demand for life-style of industrialized countries has created increasing pressures on planet making need for sustainable development to constitute the greatest challenge in human history due to exploration of natural resources and environmental issues (Matten and Crane 2005). Early work in sustainable manufacturing carried out under Environmentally Conscious Manufacturing (ECM) include consideration of source reduction, dismantling, design for manufacture, assembly and cradle-to-reincarnation concepts (Owen 1993). Its later development identified three dimensions to ECM strategy including product, process and technology. Strategies constitute famous '3-Rs' standing for reduction, remanufacturing and recycling (Sarkis and Rasheed, 1995). Current studies are on lean manufacturing, product design and '3-Rs'. Green manufacturing is one potential strategy of process technology to reduce depletion of non-renewable raw materials for safer future. Elkington (1997) said 3Ps (people, planet and profit) or 3BL (Triple Bottom Line) underlines sustainable development not only in environmental but also include socio-economics.

2.0 EARTH AND CONSEQUENCES OF HER EXPLOITATION

Planet earth unlike other known planets is made of the following constituents:

- The atmosphere is outer most surrounding of solid mother earth made of distinct layers of gases that protect her from adversities of neighbours in the galaxy system.

- ❖ Earth surface is the solid portion of earth made up of approximately 30% land and 70% water which distinguishes from other planets.
- ❖ The land mass called lithosphere is made up of rocks, soil and water mass made of:
    - Hydrosphere including ocean, lake, sea, rivers and underground water
    - Cryosphere forming the coldest portion of glaciers, snow and sea ice.

This lecture we will not be concerned about geography of earth but on exploitable portion, lithosphere for manufacturing of goods, how such activities affect sustainability of his living, environment/ecosystem and how these adversities can be mitigated by green manufacturing. Unprecedented sky rocketed rise in standard of living is beyond qualification; consequently the two major concerns are: exploitation of raw materials from earth and discharge of wastes.

2.1 Structural composition of exploitable earth

Human activities use equipment, facilities, infrastructure, raw/finished materials whose origin are from natural resources extracted from mother earth. Structure of earth can be defined in two ways based on mechanical properties, archeology/chemistry. Mechanically, it is divided into mesospheric mantle, lithosphere, asthenosphere, outer/inner cores. Chemically, it can be divided into crust, upper/lower mantles and outer/inner cores. Figure 2.1 shows the general structure from which gaseous, liquid and solid minerals are exploited (Jordan, 1979).

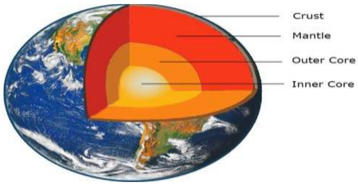


Fig. 2.1a:-Structural composition of earth.

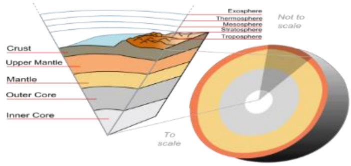


Fig.2.1b:-Section of earth's multiple layers.

Knowing the compositional of layers of earth facilitates appreciation of its massive economic value. The crust makes less than 1% of earth mass consisting oceanic and continental crusts often more of felsic rock. Lithosphere is composed of both crust and portion of upper mantle that behaves as brittle rigid solid. Asthenosphere is partly molten upper mantle material that is plastic and can flow. There are two types of crusts; each with its distinctive physical and chemical properties. Continental crust is made up of igneous, metamorphic and sedimentary rocks with composition of granite. Because it is thick with low density, continental crust rises above mantle than oceanic crust that sinks into mantle to form basins. When filled with water basins form planet oceans. These properties fit ultramafic rock peridotite, made of iron and magnesium-rich silicate minerals. Calculations indicate that the core is about 85% iron with nickel metal making up 15% balance. If core wasn't metal earth will not have been magnetic.

Recent studies suggest innermost core is enriched in gold, platinum and siderophile elements.

It is endowed with numerous resources; the exploitation of which man has found very vital in raising his economic status. Materials of economic value are categorized generally into three broad classes. The group consists of rocks which are aggregates of minerals and many types igneous rocks cooled from liquid melt sedimentary and metamorphic material. The elements combine in variety of ways to form organic carbon-containing compounds that are residues of once living creatures in form of geologically rare wood, peat, lignite/coal and oil decomposed with oxygen (Jordan, 1979). Figures 2.2 show some earth minerals and a rig erected to tap valuable earth liquid minerals (https://www.jstor.org/stable/10.7249/tr649tbna-teda.18).

Fig.2.2(a):-Typical earth mineral (b):-Liquid/gaseous mineral extraction rig.

Elements combine in a variety of earth material to form metals. These include solids made of metallic elements; melts which are rocks heated to liquid; magma that is molten rock beneath earth; lava which is molten rock at surface; and volatiles that are materials turned into gas at surface temperatures. H_2O, CO_2, CH_4 and SO_2 volatiles are released from volcanic eruptions.

2.2 Earthquake as an aftermath of exploitation of earth materials

Over exploration and extraction of earth materials as mineral raw materials for manufacturing activities create imbalance, void, crack and stress. Attempts to re-establish equilibrium may cause massive interactions resulting in effects like earthquake, tsunami and landslides e. t. c.

Earthquake is the shaking of earth surface resulting from sudden release of energy in earth lithosphere that create seismic waves that range in size from weak that cannot be felt to those violent enough to toss people around and destroy cities. It is used to describe seismic event generating waves. Figure 2.3 (Ohnaka, 2013) shows three types of earthquake causing faults which happen due to ruptures of geological events such as volcanic activity, landslides, mine blast and nuclear tests in forms of inter-plate earthquakes as normal, reverse and strike-slip. Normal and reverse faults are samples of dip-slip where displacement along fault in direction of dip and movement on them involves vertical component.

Normal faults occur mainly in areas where crust is extended like divergent boundary (Ohnaka, 2013). Reverse faults occur in areas where crust is shortened at convergent boundary. Transform boundaries are types of strike-slip fault. Reverse fault occur in areas where crust is shortened at convergent boundary.

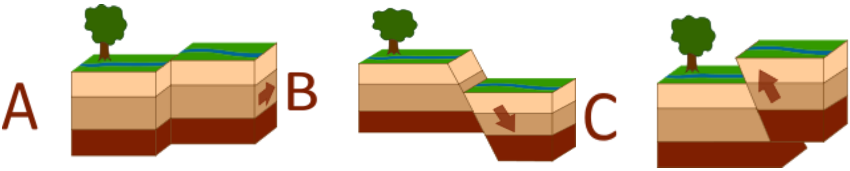


Fig.2.3:-Types of earthquake faults: A-Strike slip; B-Normal; C-Thrust *(Source Ohnaka, 2013)*

Transform boundaries are a type of strike-slip fault. Most earthquakes are caused by motion on faults having components of both dip-slip and strike-slip called oblique slip. In Figure 2.4 are maps of earthquake epicenters, distributions and collapsed building caused by earthquake. Thus over exploitation of earth triggers earthquakes through mining activities that create voids which the earth tries to balance the pressure therein (National Research Council U.S, 2003). Figure 2.4a, Africa shows fewer threats of quakes due to her low exploitation status.

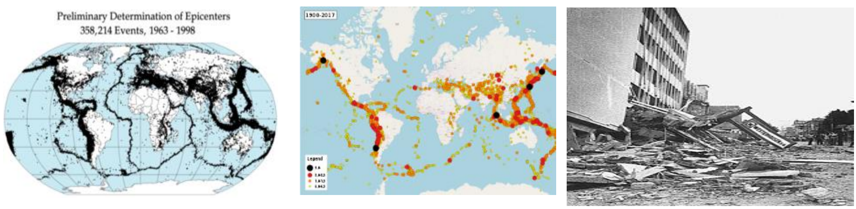


Fig. 2.4 (a): Earthquake epicenters (b) Earthquakes 1900- 2017 (c) Collapsed quake-building

3.0 CONVENTIONAL MANUFACTURING AND ITS ADVERSERIES

Manufacturing is production of merchandise for use using labour, tool, machine, chemicals and biological processing or formulation. The term refers to range of human activities, from handicraft to high tech. It begins with product design, material specification and production through processes to parts. Modern manufacturing includes intermediate processes required in production/integration of product. After industrial revolution, capabilities of manufacturers to mass produce goods for human needs has brought adverse effects on earth by discharge of solid, liquid and gaseous waste shown in Figures 3.1a-b. Emerging technology has provided new growth in advanced manufacturing and employment opportunities. It provides important material support for national infrastructure, defence e. t. c but however its activities involve significant social and environmental cost. Efforts to solve them include use of bio-based raw material/industrial symbiosis, efficiency, reduced waste and elimination of harmful chemical by green manufacturing. Modern manufacturing has improved human lives but also brought immeasurable disasters like earthquake, floods and climate change (Despeisse *et al.*, 2010).

Fig. 3.1(a): Assembly plant of Boeing 787.

Fig. 3.1(b): Heavy steel semi-products on display

(Source *Kalpakjian S., Steven S., 2005)*

Table 3.1 shows a list of top 20 manufacturing countries for 2014-2017 (World Bank Report, 2018). No African country is listed despite her equitable share in attendant adverse effects.

Table 3.1 List of 20 top world manufacturing countries in dollars *(World Bank Report, 2018).*

Rank	Country/Region	Millions of $US	Year
	World	12,308,110	2016
1	China	3,590,978	2017
	European Union	2,512,108	2017
2	United States	2,160,559	2016
	Eurozone	1,931,828	2017
3	Japan	1,041,770	2016
4	Germany	759,904	2017
5	South Korea	422,065	2017
6	India	389,508	2017
7	Italy	284,297	2017
8	France	261,831	2017
9	United Kingdom	241,354	2017
10	Indonesia	204,726	2017
11	Brazil	208,735	2017
12	Mexico	196,816	2017
13	Spain	171,317	2017
14	Russia	188,013	2017
15	Canada	175,959	2014
16	Turkey	149,038	2017
17	Switzerland	123,184	2017
18	Thailand	123,220	2017
19	Ireland	97,967	2016
20	Netherlands	88,817	2017

3.1 Manufacturing and waste generations

Manufacturing involves conversion of raw materials into goods using machineries and tools. Some wastes provide raw material for other consumer product industries. Liquid/solid wastes are discharged into water and soil while gaseous wastes go to atmosphere. Imperfections of waste treatments leave remnants that affect environmental health, stability and sustainability. Liquid and solid industrial wastes cause water pollution which greatly affect aquatic lives and dislocate toxic balance of soil posing big threat to plants, animals and the entire earth.

3.2 Effects of manufacturing emissions on earth's atmosphere

Gaseous industrial wastes escape to interact with atmospheric compounds distorting the thick ozone layer covering earth from harmful radiations of outer solar system. Figure 3.2a-b show emissions from manufacturing (Tan *et al.*, 2010). The problems caused by manufacturing discharges to the ecosystem are huge and multifarious. Solid/liquid discharges to land/water; cause soil and aquatic management problems. Figure 3.2(c) shows how CO_2 is absorbed into ecosystem. Green house gases like carbon monoxide (CO), methane (CH_4) carbon dioxide, sulphur hexafluoride (SF_6) nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbon (PFC), chloroflourocarbon (CFC), hydrochloroflourocarbon (HCFC) and others are released.

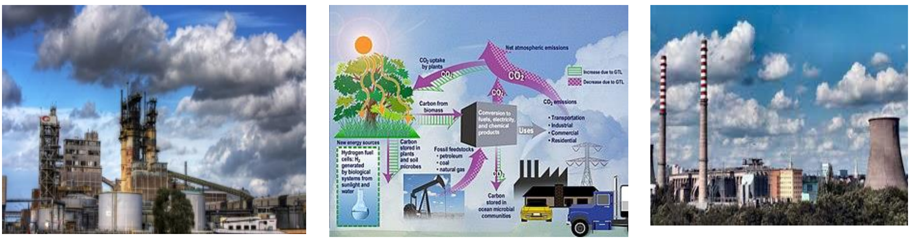


Fig.3.2:-Emissions from (a) petrochemical plant (b) Power plant. (c) Flow of CO_2 in ecosystem

(Source: Tan et al., 2010)

These react with Ozone (O_3) layer that provides thick blanket atmospheric cover that shields earth from sun's heat and infra-red radiation. The overall effect of these is climate change manifesting in various forms of global warming, flood/tsunamis, irregular rainfall, landslides, shrinking rivers/lakes e. t. c. that has led to big challenges to sustainability. Immediate and direct consequences of these are loss of arable land, damage to aquatic life, food insecurity, inter-communal conflict and so on (https://www.environmentalscience.org/sustainability). The world must solve the problems in order live in harmony with nature without annihilation.

4.0 WHAT HAS THE WORLD DONE TO SOLVE THE PROBLEMS?

The broad and general approaches adopted by the world through the umbrella body of United Nations are multifarious including the following:

- Advocacy for sustainable manufacturing by use of renewable materials.
- Creation of awareness for development and use of renewable energy.
- Ecological reconstruction, rehabilitation and public health regulation.
- Standardization for treatment and discharge of industrial wastes.
- Regulations for the protection of environment, fresh water and fauna.
- Regulations on industrial emissions, waste discharge and treatments.

One of the key efforts at regulating environmental destruction by manufacturing is the Kyoto Protocol which seeks to control green house emissions. It is an international treaty under United Nations Framework

Convention on Climate Change in 1992 that committed parties to reduce greenhouse gas emissions based on the scientific consensus in (part one) that global warming is occurring and (part two) that most likely man-made emission has predominantly caused it (https://unfccc.int/kyoto_protocol). It was adopted in Kyoto, Japan in 1997 but it became effective in 2005 with 192 parties. It implemented objectives of UNFCCC to reduce the onset of global warming by lowering greenhouse gas emission in atmosphere to level that will prevent dangerous anthropogenic interference with the climate system" (Article 2). The Protocol applies to six greenhouse gases listed in annex A as; carbon dioxide (CO_2), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrous oxide (N_2O). It noted that individual country has varied capability to combat climate change due to her economy and therefore puts obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of greenhouse gases. It has manifested in stages up to United Nations Conference on Climate (COP 26) held in 2021. The restriction favoured Africa to develop green manufacturing.

5.0 MY CONTRIBUTION AT SOLVING THE NEGATIVE IMPACTS

My contributions to part solve the effects of manufacturing on earth, environment, climate and humans are hereby presented in different aspects of production engineering as follows:

(a) Bonding technology
(b) Composite technology
(c) Lubrication technology (tribology)

5.1 Bonding Technology

In manufacturing, several materials are added together to form component parts. Solid bodies are added by welding, soldering, gluing and other joining processes while liquids are mixed. Particulate substances are brought together by sintering, bonding e. t. c. In bonding the binder phase is usually provided by synthetic resins from mineral sources or natural resins obtained from sources such as plant gums, molasses, starch and dextrin from tubers and cereals. One of my signature works is use of gum Arabic for bonding applications in metal manufacturing.

5.1.1 Utilization of Nigerian acacia species as binder in metal manufacturing

Nigeria produces four grades of acacia species in commercial quantities that are not used in local industries but exported. Grades 1 and 2 that are preferred by importer countries are used in pharmaceutical, confectionary, food, textile and beverage industries leaving grades 3 and 4 with little or no values. Nigerian foundries use imported materials for binding their synthetic casting sand due to non development of locally available materials. This research investigated suitability of Nigerian gum Arabic to bind sand. Standard equipment were used to determine melting point, optical rotation, specific gravity, PH, water solubility, moisture/volatile matter, metal/sulphate ion content and macro-structural analysis of each grade of gum Arabic to assess its potential as alternative to mineral and chemical binders like clay, silicates, phenols, ketones, formaldehydes and other synthetic resins that are hazardous to man and equipment. Binders are constituents of synthetic foundry sand and usually grouped as mineral materials, organic binders, inorganic binders or miscellaneous binders based on source and chemical composition. Acacia species exudates are natural resins that contain arabin; semi solidified sticky fluid oozing from incision made on bark of acacia trees. Nigeria produces different grades of exudates and is ranked as second largest world producer after Sudan with an annual production of 20,000 tonnes (Ademoh and Abdullahi, 2009[1]). Figure 5.1 shows sections of acacia species tree and Figure 5.2, export of it from Sudan, Chad and Nigeria for 1990-2003. Hirst *et al* (1989) said acacia species is used in pharmaceutical, confectionary, food, textiles and beverage production. The properties may be utilized for bonding foundry sand to replace mineral binders that deplete earth. Acacia species is considered as the oldest and best known of natural gums since 2650 BC. It is called ancient ingredient of 21st century. It is reported as most abundant natural exudates in Nigeria. Average minimum and maximum temperatures that make trees grow are 14^{0}C and 40^{0}C and are in Borno, Yobe, Sokoto and Bauchi States.

Fig.5.1-Acacia Senegal with gum Arabic.

(Source:https://www.feedipedia.org/node/342)

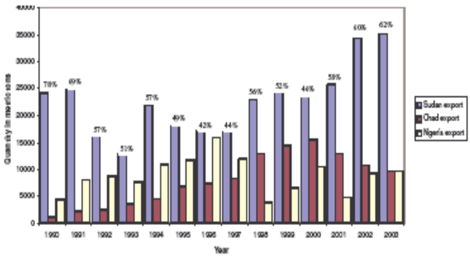


Fig 5.2-Acacia export from Sudan/Chad/Nigeria 1990-2003.

(Source: Ademoh and Abdullahi, 2009[1])

Fennema (1996) described it as complex variable compound mixtures of arabino galactan oligosaccharide, polysaccharide and glycoprotein of less consistent than other hydrocolloids; depending on source its glycan components contain more L-arabi, D-galactose, D-galactose relative to L-arabinose. It has 4-0-methyl-D-glucuronic, less L-rhamnose, unsubstituted D-glucuronic acid and low molecular polysaccharide as major component and high molecular hydroxyproline glycoprotein as minor component. As mixture it varies much with source and exact molecular structure is uncertain. IR analyses showed it is made of polysaccharide with flexible/compact conformation dissolving in water into a low viscosity Newtonian fluid. It is soluble in organic solvents, has low reactivity; excellent emulsifying, foam stabilizing and adhesive properties. It doesn't interfere with blended product, has pale colour, no odour/taste.

5.1.2 Commercial grades and industrial uses of Nigerian gum Arabic

Four grades of gum Arabic are produced in commercial quantities in Nigeria Osagie (2002):

a) Acacia Senegal (hard gum):-known as grade 1, sourced from Yobe and Borno states.

b) Acacia Seyal (friable gum):-known as grade 2, sourced from Bauchi and Jigawa states.

c) Combretum:-It is commercially called grade three, has a negative optical rotation and is sourced from the 14 states of Nigeria.

d) Neutral:-Fourth variety of gum Arabic without definite biological name.

Industrial uses of acacia species are as powder or in oil for suspending sensitizer for hard coat on paper, masking agent, combined with sensitizer and pigment for print. It is used in melting yarn chip processes to make yarn stronger and can be added to paint formula to fix pigments in textile fabrics to save cost. It is used as binder for pigments in watercolor, gouache paints; in aluminum plate process and in plano-graphic offset lithography mixed with water paint for brighter colour, for scented ink/black ink and injection mould for paraffin removal. It is good in flavour fixation, emulsifier, demulcenting qualities for breaking surface tension inside soda and witchcraft as better wear resistant option to chalk. Gum Arabic is used in pharmaceutical (lotion, syrup, liver oil); confectionery (beverage/cake); food (dietetic cake, special food); cosmetic (lotion, cream, emulsion, facial mask); adhesive for paper and liquid gum for office use (Ademoh and Abdullahi, 2009[1]). Figure 5.3a-d show four distinct Nigerian acacia grades. Grade 1 is clear light yellow colour of average lumps, grade 2 is dark yellow of bigger lumps. Grade 3 is light brown smaller lumps. Grade 4 is dark amber brown of large irregular lumps.

Fig. 5.3a: Raw gum Arabic grade 1.

Fig. 5.3b: Raw gum Arabic grade 2.

Fig.5.3c:-Raw gum Arabic grade 3.

Fig.5.3d:-Raw gum Arabic grade 4

(Source:Ademoh and Abdullahi, 2009[1])

This motivated its use as sand binder in foundry industry. For optimum performance, Dietert (1966) suggested that binders should be in concentrated form, not settle out in storage tank, be in single package, easy to handle, not impair flowability of sand mixture, make patching easy and slow to air dry. Also good binders should be easy to mix with sand, lend it to being worked with dry/damp run of mine sand, cause minimum cleaning of mixing equipment, not stick to wall of mould/core boxes, not drain to bottom of mixed sand and lend itself to green strength control. A binder must possess good warm strength, easy to bake, not sensitive to oven atmosphere; be such that baked mould/core will free itself easily from drier/plate and has low moisture absorption. These motivated its use for foundry applications.

5.1.2 Application of acacia species exudates in foundry

The research determined melting point, optical rotation, specific gravity, water solubility, PH, moisture/volatile matter, metal/sulphate ion and macro-structural compositions of each grade acacia species. Melting point was measured with Stuart equipment. Destro-rotary polarimeter was used to determine optical rotation of sample while gas jar method was used to measure specific gravity in accordance with BS1377 (1990). Solubility at 30^0C for each acacia grade was measured according to BS1377. Kent EIL7020 PH meter equipped with combined glass electrode was used for PH of 1% solution of gum Arabic in distilled water. Each was oven evaporated at 100-104^0C for 30 minutes and reweighed (Ademoh and Abdullahi, 2008). For chemical analysis, acacia was ashed in preparation for metal and sulphate ion analysis.10g of it was oven dried at 102^0C, burnt to carbonize and ashed at 450-500^0C in muffle furnace for 2 hours. Ash was digested with 1:1 HCl and HNO_3 until white fumes evolved. $20cm^3$ the ash was added boiled for 10 minutes and filtered to $100cm^3$flask. Filter paper was rinsed many times and volume made up to mark. Solution was transferred to container for AAS (metal ion) analysis. Sulphate ion (SO_4^{2-}) was analyzed by HACH DR water spectrometric method.

The property analyses were done in accordance with established standard IBF. Moulded sand was made with test specimens made from sand bonded with 30% gum Arabic; 70% water and sand specimen bonded with powdered gum Arabic. Mould specimen used procedures approved by IBF and AFS. Sample sand was oven dried at 110^0C and sieved to separate BS standard grain sizes of 40-72 used to produce standard specimens. Selected grain was mixed in roller for 10 minutes for evenness before moulding. Specimens dimension were diameter-5.08cm and height-5.08cm. Universal ramming equipment was used to ram sand mixes to standard test mould shown in figure 5.4. Ramming statistics used IBF and AFS standards of (dropping) weight 6.5 Kg; 3 compaction blows; falling from a height of 5.08cm with average weight of 130g. Specimens were made with different sand mixes and subjected to tests to measure standard foundry property values. Small sand specimen was compressed in prong of teller speedy moisture teller and instantaneous reading of moisture (%) was made from gauge. For green permeability; air pressure of $9.8x10^2N\backslash m^2$ was passed through sample tube with sand specimen placed in permeability meter for test. Time taken by $2000cm^3$ air to pass through was read. The permeability meter drum produced constant pressure of $10g/cm^2$:

Ω = vђ/ρðŧ…………………………………….. (5.1).

Green compressive strength tests:-Steadily increasing compressive force was applied on specimen until failure occurred and the strength (KN/m^2) was read instantaneously from the universal strength machine of model 084M2. Specimens were first oven dried at 110^0C for an hour and then cooled to room temperature. Green/dry compressive strengths are properties referred to as bond strength and are based on formula (Ademoh and Abdullahi, 2010):

§ = ∂ x 62 x ρ/ Б……………………………………….(5.2)

Where §=bonding strength (green or dry compressive); ∂=diameter of specimen =5.08cm; P=pressure delivered by the equipment and;

Б =cross sectional area of test specimen = $\frac{\prod x(d)^2}{4} = \frac{3.24}{4} (5.08)^2$ $=20.258cm^2$. ….. (5.3)

Green hardness test equipment B-scale model MOA0731M was adopted for the test. Steadily increasing compressive force was applied on specimen until failure occurred and strength (in $KN^/m^2$) was read from machine. Over size sand grain was noted to measure shatter index as:

% Shatter index = <u>weight of sand retained on sieve X 100</u>

Total weight of AFS specimen ……….. (5.4)

Fig. 5.4:-Moulding sand specimens.
(Source: Ademoh and Abdullahi, 200)

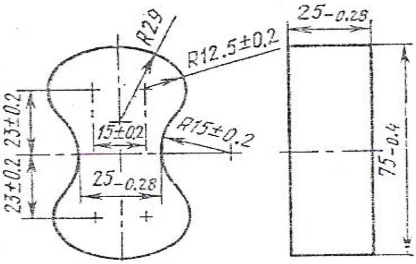


Fig. 5.5: Core tensile strength test specimen
(Source: Ademoh and Abdullahi, 2010)

Core analysis was done at Ajaokuta. Specimens (Figure 5.4) made from base sand bonded with 30% gum Arabic/70% water were analyzed using IBF and AFS procedures. Specimens were grouped together and oven baked at 160^0C, 180^0C, 200^0C, 220^0C, 250^0C for defined periods and cooled overnight in oven in desiccators for dehydration before tests (AFS, 1989). Figure 5.7 shows melting and decomposition point of each grade of acacia species. In figure 5.8 is optical rotation, used for grading acacia. Specific gravity that tells viscosity/adhesivity of each grade is in figure 5.9. PH that indicates acidity is in figure 5.10. Figure 5.11 is water solubility and figure 5.12 is moisture/volatile matter of acacia species. Table 5.1present ion and sulphate compositions showing the three groups of elements contained in gum Arabic.

Table 5.1: Chemical Composition of Gum Arabic *(Source: Ademoh and Abdullahi, 2009)*

Gum Arabic Grade	Compositional Constituents (mg\L from Solution of 100g\L)								
	K	Na	Mg	Ca	Mn	Cu	Zn	Fe	SO_4^{2-}
Grade 1	5.11	5.53	2.41	4.76	0.84	0.16	0.09	2.49	4.00
Grade 2	3.71	3.59	1.42	4.02	0.33	0.16	0.03	1.41	1.00
Grade 3	2.03	4.54	1.29	4.80	0.858	0.18	0.05	3.72	1.00
Grade 4	2.66	3.64	1.67	1.60	0.24	0.27	0.39	1.48	1.00

They are group I (potassium, sodium), group II (magnesium, calcium), alkaline earth metals (manganese, copper, zinc and iron) in electrochemical series. Their reactivity with oxygen gives strong bond with sand. Grade 1 acacia had the highest weight of the elements (21.48) followed by grade 3 (17.65), grade 2 (14.54) and then grade 4 (14.52). Sulphate ion content is highest in grade 1 (4.0) and others are 1.0. By alkaline earth metal content (Mn, Cu and Zn), grade 2 is least toxic followed by grades 1, 4 and 3 are most toxic though within limit. Grade 1 was most active then grades 3, 2 and 4. Its polysaccharide organic component made it very reactive; its multiple diradical group (-COOH) react with sand to give strong bond. In figure 5.6 are some automotive castings exhibiting cavities made with core implants.

Figure 5.7 showed that grade 1 had highest melting temperature then grade 2, 3 and grade 4. Melting point average of 178-210^{0}C was within range of organic core binders like vegetable drying oil. This is good for foundry use as it fluidized at high temperature, hold sand together strongly to withstand casting pressure. Optical rotation told angle of diffraction of polarized light through it as in Figure 5.8 (used to classify material). All species have positive optical rotation. Grade 4 has least rotation followed by 1, 2. Grade 3 had over 200% of other grades.

Fig. 5.6: Parts cavities made by cores
(*Source*: *Kalpakjian S., Steven S., 2005)*

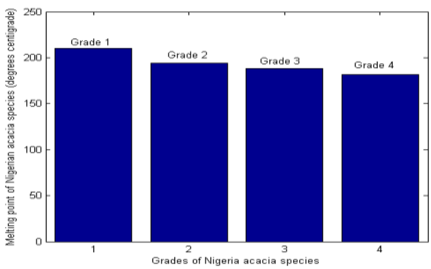
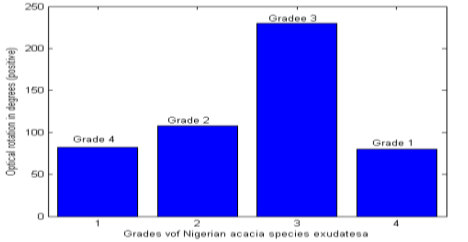


Fig 5.7: Melting points of acacia species
(Source: Ademoh and Abdullahi, 2009)

Optical rotation inversely relate to specific gravity, viscosity and adhesiveness. Grade 4 gave higher strength than grades 1, 2 and 3. Grades 1/4 both had specific gravity 1.10g\cm^3 grade 2 (0.9g\cm^3);

grade 3 (0.7g\cm^3). Grades 1/4 had similar adhesive property and higher bond.



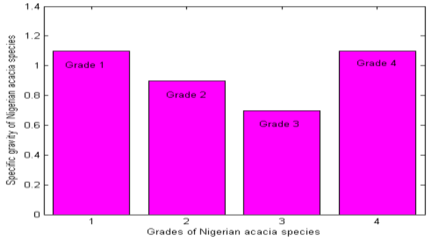
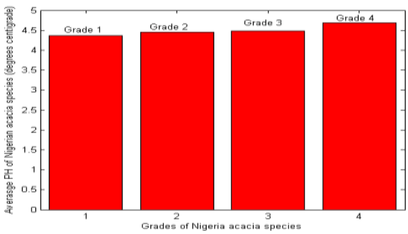


Fig 5.8: Optical rotation of acacia species

Fig 5.9: Specific gravity of acacia species

(Source: Ademoh and Abdullahi, 2009)

Grade 4 was the least acidic, followed by grade 2, 3 and grade 1, most acidic. PH was within the weak acid range of 4.68 for grade 4 to 4.36 for - grade 1 as shown in Figure 5.10. It meant non-corrosivity to humans, working tools and equipment; satisfying a very vital attribute of foundry sand binders. Its water solubility presented in Figure 5.11 showed it is high. It forms a clear solution in water. But it is insoluble in organic solvents. Its water solubility made it very versatile forming non-corrosive aqueous solution. Grades 1 and 4 had equal solubility, followed by grades 3 and 2. Grades 1 and 4 acacia are better binders than grades 3 and 2.



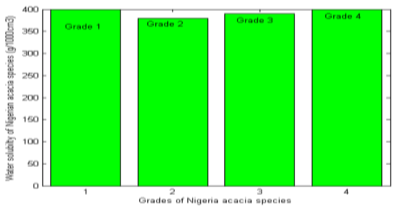


Fig.5.10:-Average PH of acacia species

Fig.5.11:-Water solubility of acacia in g/1000M^3

(Source: Ademoh and Abdullahi, 2009)

Moisture and volatile matter of acacia exudates presented in Figure 5.12 showed grade 4 had least moisture; grade 1 had highest volatile matter. Grade 4 gave least gas at high temperature and most preferred. Its mould will produce less casting defects by gas evolution.

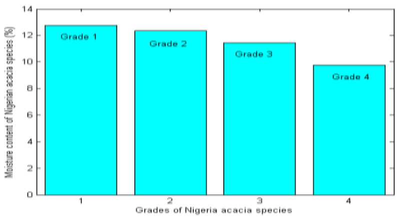


Fig. 5.12:-Moisture of acacia species (%)

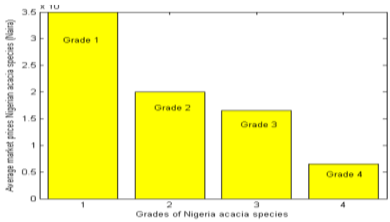


Fig.5.13:-Average prices of gum Arabic (N)

(Source: Ademoh and Abdullahi, 2009)

Moisture of10-13% is high and vents must be made in moulds for easy gas escape. Grade 4 needed more protection from atmospheric vapour as it is hygroscopic and has shorter shelf life. The average annual prices peak harvest and off peak periods of Nigerian gum Arabic are in Figure 5.13 (Ademoh and Abdullahi, 2009). Grade 1 is most expensive followed by 2, 3 and grade 4, the cheapest though not as costly as imported binders giving low export value.

Moulding sand results and discussion:- Mould test results were compared to standard in table 5.2. In Figure 5.14 moisture of grade 1 mold varied from 2.0-1.7%; grade 2 from 2-1.8%; grade 3, 2.3-1.9% and grade 4 from 2.2-1.8%. Grade 3 moulds were most then 2; 4 varied by 0.3%; 0.4% for grades 2, 3 and 4. In Figure 5.15 grade 4 was strongest then grades 1, 3 and 2. It showed trend of suitability for green casting in order of grade 4, 1, 3 and 2. 9-13% grade 1 was suitable for casting of non-ferrous alloys; malleable/heavy grey iron; 9-13% grade 2 for magnesium and non-ferrous; 9-13% grade 3 for non-ferrous, malleable, light grey iron and steel; 9-13% grade 4 is good for green casting of heavy steel (Ademoh and Abdullahi, 2013).

Table 5.2:-Satisfactory property ranges for sand castings *(Source: Ademoh and Abdullahi, 2009).*

Metal	Green Comp Strth [KN|m^2]	Perm. No	Dry Strgth [KN|m^2]
Heavy Steel	70-85	130-300	1000-2000
Light Steel	70-85	125-200	400-1000
Heavy Grey iron	70-105	70-120	350-800
Aluminum	50-70	10-30	200-550
Brass & Bronze	55-85	15-40	200-860
Light Grey iron	50-85	20-50	200-550
Malleable Iron	45-55	20-60	210-550
Medium Grey Iron	70-105	40-80	350-800

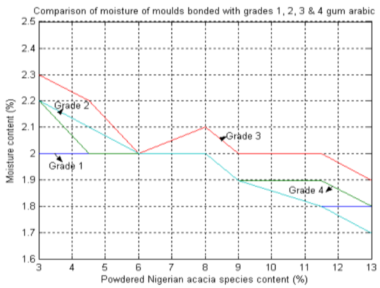


Fig 5.14: Moisture (%) of sand moulded of with grades of Nigerian gum Arabic.

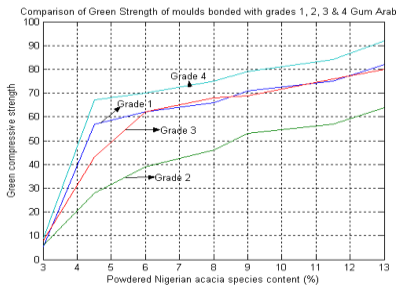
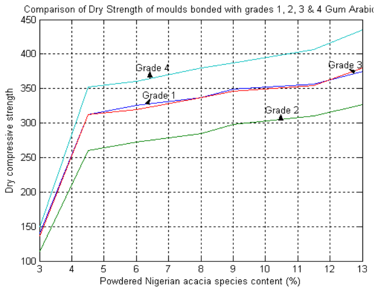


Fig.5.15: Green compressive strength (KN\m^2) Sand moulded with grades & 4 gum Arabic.

(Source: Ademoh and Abdullahi, 2009)

Dry compressive strength (Figure 5.16) grade 4 had highest strength followed by grades 1, 3 and 2 showing order of suitability for dry mould. In a study, 9-13% grade 4 was suitable to dry cast light steel/iron; 9-13% grade 3 for non-ferrous alloy, malleable/light grey iron; grade 2 for non-ferrous alloy; grade 1 for dry casting of non-ferrous and malleable/heavy grey iron.



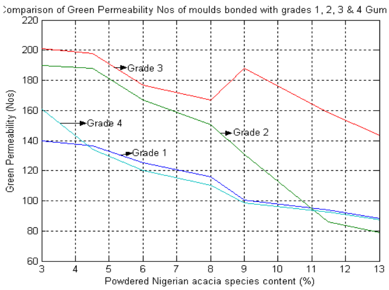
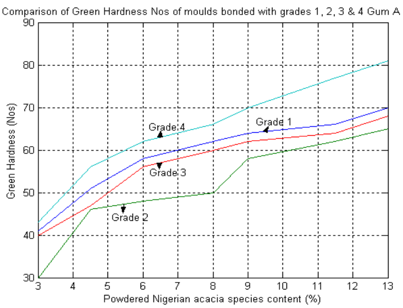


Fig 5.16: Dry Compressive strengths (KN\m^2) of sand moulded with grades of gum Arabic.

Fig. 5.17 Green permeability (No) of sand moulded with grades of acacia species

(Source: Ademoh and Abdullahi, 2009)



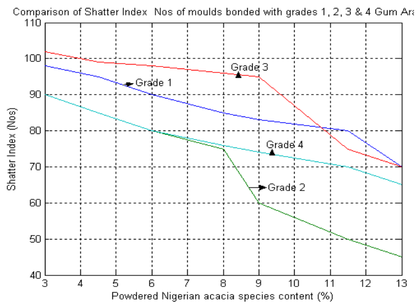


Fig 5.18 Green hardness of sand moulded with Nigerian acacia species

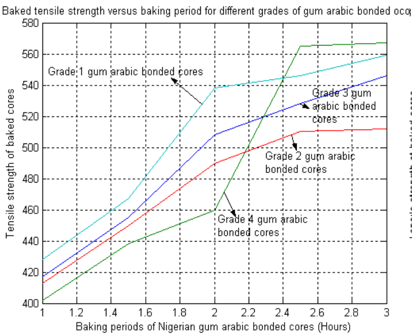
Fig 5.19 Shatter Index of sand moulded with Nigerian acacia species exudates

(Source: Ademoh and Abdullahi, 2009)

Green permeability in Figure 5.17 showed grade 3 mould gave easiest gas escape, followed by grade 2, 1 and 4 moulds that needed additional vents for steel casting. In Figure 5.18 is green hardness showing grade 4 mould had highest abrasion resistance then grades 1, 3 and 2. Figure 5.19 showed grade 3 mould had highest shatter index then grades 1, 4 and 2 mould. So grade 4 gum Arabic offered best all round result followed by grades1, 3 then 2 in that order.

<u>Core results and discussion</u>:-Result of cores baked at 160^{0}C is shown in Figure 5.20. Tensile strength increased with baking temperature for gum Arabic grade, because class 3 core binder melts at high temperature

to bind sand and cools to form strong bond. At 160^{0}C no grade attained melting point at which this property is fully displayed, accounting for non attainment of peak tensile strength. It increased with baking enabled cores more reaction time.



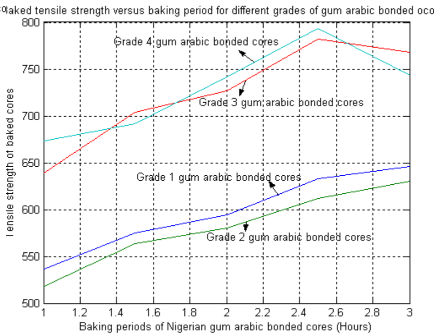
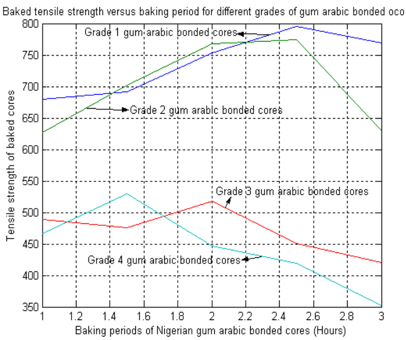


Fig 5.20: Tensile strength (KN/m^2) of gum Arabic cores baked at 160^{0}C for 1-3 hrs.

Fig 5.21:Tensile strength gum Arabic cores baked at 200^{0}C for 1-3 hrs (KN/m^2) of

(Source: Ademoh and Abdullahi, 2010)



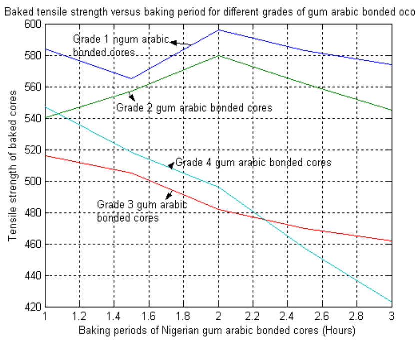


Fig 5.22:-Tensile strength (KN/m^2) of gum Arabic cores baked at 220^{0}C for 1-3 hrs.

Fig 5.23:-Tensile strength (KN/m^2) of gum Arabic cores baked at 250^{0}C for 1-3 hrs.

(Source: Ademoh and Abdullahi, 2010)

Melting point of gum Arabic was determined to be 200-210^{0}C, 190-194^{0}C, 184-188^{0}C; 178-182. Baked grade 4 core had highest strength then grades 3, 1, 2; showing trend of usability. Strength of grade 2 cores was overtaken by grade 1 due to chemical reactivity, adhesiveness and water solubility. In 5.21 core baked at 200^0C for 1-3 hours increased strength for grade 3 and 4 cores at 2.5 hours and then dropped. Grades 1 and 2 cores increased with time without peak as 200^0C was 20^0C, 12^0C and 6^0C above melting points of grades 4, 3 and 2 acacia and 5^0C lower than that of grade 3. Grades 3, 4 attained peak strength at 2.5 hours but grade 2 and 1 acacia cores didn't. Optimum strength at 200^0C implied lower heat and production costs.

Comparatively tensile strength of 8% acacia grade 1 cores are 3.7% higher than grade 2; 7.8% and 8% lower than grades 3 and 4 after 2.5 hours baking. Figure 5.22 showed result of core baked at 220^0C. Over-baking grades 3 and 4 cores (40^0C-32^0C above melting) decreased strength as binder burnt. Grade 2 and 1 acacia cores acquired enough heat to give optimum properties as strength peaked at 2.5 hours. Grade 1 cores gave highest strength followed by grade 2, 3 then grade 4. Strength of grade 1 bonded core was 2%, 40% and 45% higher than cores of grades 2, 3, 4 in order of suitability. In figure 5.23 grades 4, 3 cores baked at 250^0C, strength decreased after 1 hour, grade 1; 2 hours baking. But grade 2 acacia cores increased up to 1½ hours and dropped. Thus core made with acacia binder shouldn't be baked at 250^0C.

5.1.3 Findings and the way forward

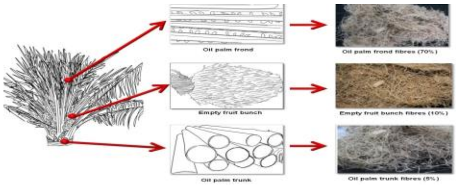
The study found that all grades of gum Arabic as effective foundry binders. Grade 4 acacia species with little export value had the best binding potential for sand mould/core. Its use will reduce use of mineral binders and promote planting of acacia trees. Thus all targets of green manufacturing of environmental protection; social responsibility and economic practice are fulfilled. Consequent upon a PhD work on gum Arabic as resin binder for non-asbestos brake pad was recently completed. Another one for its use as welding electrode binder is ongoing.

5.2 Composite Technology

Composites are engineering materials created from multiple substances whereby one serves as matrix and their major constituent as filler with material exhibiting improved properties for multiple uses. Composites may be synthetic, natural or mixture and have offered alternatives to traditional materials based on their cost and other advantages. My work on use of oil palm fibre reinforced composite is presented as representative of all other works in this area.

5.2.1 Potentials of palm fibres for reinforcement of engineering composites

Natural fibres have favourable properties like biodegradability, low density; costs and cheap availability have found wide applications in production polymeric engineering composites. Treatments have been used to address the shortcomings of water absorption and performance of the fibres. The work characterized treated/untreated fibres obtained from male flower palm bunch stalk and frond for reinforcement of polymer composites for engineering uses. This is expected to reduce dependence on non-sustainable synthetic materials. Natural fibres are eco-friendly, biologically degradable, widely available and cheap, obtained from biomass wastes which abound in farms. The materials have similar property with synthetic fibre hence; they find wide use in production of polymeric composites for engineering like reinforcement of polymers for fabricating crash helmets. Oil palm fibres are agro bye-products periodically left in field during planting, pruning and milling. Its biomass (OPB) is grouped as lignocellulosic residue typically containing 50% cellulose, 25% hemicellulose and 25% lignin in cell wall. Fibres are generated from oil palm residues like oil palm trunk (OPT), oil palm frond (OPF), kernel shell, empty fruit bunch (EFB), pressed fruit fibre (PFF) and palm oil mill effluent (POME). Palm frond account for 70%, EFB 10% and OPT about 5% of all biomass produced (Ademoh and Olasoji, 2015). Sections of fibre bearing oil palm are shown in Figure 5.24a-c.



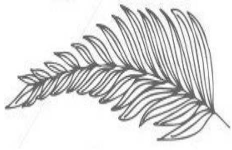


Fig. 5.24a Parts of oil palm tree   Fig.5.24b:Palm male flower bunch   Fig. 5.24c: Palm frond
(Source: Ademoh and Olasoji, 2015)

Oil palm fibre has high cellulose and potential as natural resources, but their applications account for small percent of total biomass productions. Studies showed that oil palm fibres have potential for effective reinforcement in thermoplastics and thermosetting materials. Helmets are protective head gears worn by riders for protection against injury in accident. A rider is highly prone to life threatening accidents and injuries due to the two legged and high speed nature of motorcycles. They act as face shield, provide ventilation and ear protection. Its main components are shell and inner foam liner. The shell is usually hard and helps resist objects from penetrating during impact thereby preventing direct injury on skull. The foam liner absorbs most impact energy; made from resins/plastic reinforced with fiber like aramid. It protects user by absorbing mechanical energy to prevent head injury. Besides its volume, weight is critical issue in comfort user head/neck. Neurosurgeons desire that helmet design adapt to inner head structure. Modern helmets are made from acrylonitrile butadine styrene (ABS) plastics reinforced with glass or carbon fibres, fabric/foam interior for comfort. Its inner foam is soft/thick expanded polystyrene foam designed to cushion impact. Outer shell is thin/hard, commonly made of plastic like fibre glass or Kevlar to protect rider on impact.

In Nigeria use of motorcycle for commercial transport became common by 1990s to cope with passenger population in remote areas that taxis cannot access. In 2008, Nigeria recorded staggering surge in motorcycle accidents that raised concern to enforce wearing of anti-crash helmet for safety to reduce of head/brain injury/spine injury by 85%/69% and death by 42% (Ademoh and Olasoji, 2015). Helmets are used in factory/work sites. Shuaieb *et al* (2002) made three prototype helmet shells from coir fibre hybridized with glass, oil palm fibres and polyester resin. They said glass woven layer on outside surface gave helmet higher impact resistance than coir/glass. Yuhazri and Dan (2007) used coconut fibre reinforce thermosetting polymer matrix to make motor cycle helmet. Studies have shown that hybrid of natural fiber composites gave better plastic helmet shell. Murali *et al* (2014) showed hybridized composite gave better strength, less weight and cost than acrylonitrile butadiene styrene plastic helmet of 40% composite of jute, banana, sisal fibre and 60% epoxy. These prompted this work.

5.2.2 Fabrication of safety helmet from palm fibre reinforced polymer composite

The research materials were unsaturated polyester, calcium carbonate, distilled water, cobalt naphthanate, palm male flower bunch, methyl ethyl ketone peroxide, sulphuric acid, sodium hydroxide solution, glucose assay kit, helmet mould, dinitrisalicyclic acid, autoclave, Instron machine, Ceast Resil impactor, shore D-durometer, Micro Vision Industries universal tester, plastic and steel containers. Fibre was obtained from of trees in plantation at Offa Raw fibre was treated in sodium hydroxide for property enhancement. Mishra *et al* (2008) treated sisal-polyester at room temperature and reported 4% tensile strength rise. 5% NaOH treated fibre reinforced polyester composite was used to raise strength by 10%. High cellulose induced by chemical treatment caused delignification, enhanced flexural rigidity and stabilized molecular orientation. Washed/dried fibre was soaked in 5% NaOH solution for 3hours, washed to lose slipperiness and then dried to reduce its hydrophilic state. Fibre–cell and NaOH reacted as:

Fibre-cell-OH + NaOH = Fibre cell-O-Na^+ + H ………… ….(5.5)

Mechanical test of fibre:-Tensile/strain properties of fibres were determined using Instron universal machine on five specimens of treated fibres using standard procedures. For density, quantity of dried treated sample was weighed and recorded as w. Distilled water was poured in measuring cylinder at initial volume as V_1.Weighed fibre was put into the cylinder with water and final volume as V_2. This was repeated and density calculated (Mishra *et al* 2008).

$$\frac{W}{V2-V1}\ x\ 1000\ \text{Kg/cm}^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (5.6)$$

Bio-composite formulation:-Treated dried fibre of male stalk flower bunch was weighed and used to formulate composites mix in Table 5.3. Open mould casting by hand lay-up method was used to fabricate helmet shell. As in previous works it aided fast product development sequence at less cost. Yuhazri and Dan (2007) used the method for composites to fabricate exteriors/interiors of low quantity polymer helmet. Pigmented gel was coated inside mould for fine surface finish, allowed to cure and reinforcing mat was placed in. Catalyzed resin and filler was poured, brushed in with manual rolling to remove entrapped air, compact and resin.

Table 5.3: Constituent of the in formulation of bio-composite *(Source: Ademoh and Olasoji, 2015)*

S/N	Constituent	Name of constituent	Composition (%)
1	Matrix	Unsaturated polyester	70
2	Reinforcement	Oil palm male flower bunch stalk fibre	20
3	Filler	Calcium carbonate	8
4	Accelerator	Cobalt naphthanate	1
5	Catalyst	Methyl ethyl ketone peroxide	1

More layers of mat, woven roving and resin were made repeatedly to arrive at the required thickness. Curing was aided by addition of catalyst and accelerator without external heating. Figure 5.25 shows the processes in the production. For casting, treated fibre was chopped in length of 5-20mm and mould treated with release agent to ease product removal. Fibre was wet with resin, laid/brushed in to apply, cured for 40 minutes and removed from the mould.

(A) (B) (C) (D)

Fig.5.25: Helmet production processes (A)Helmet open mould; (B)Treated chopped fibre; (C) Internal surface of helmet pattern; (D) External surface of helmet pattern. *(Source: Ademoh and Olasoji, 2015)*

Specimens were cut out from composite shaped at the Technology Incubation Centre Bauchi. Mechanical/physical test of specimens with Ceast Resil impactor machine were conducted on samples dimensioned 85x8x3 mm according to ASTM D256. Each sample was set as vertical cantilever and broken with swing of hammer with speed of 3.4 m/s and energy of 4J. Impact strength (J/m) was calculated by dividing the energy absorbed with thickness of specimen. Hardness test was done according ASTM (D2240) using Shore D durometer. Tensile test was done with ASTM D638 standard on universal machine. Toughness was deduced from stress-extension, representing area under stress extension curve. For water absorption the initial dry weight (W_d) of specimen was determined and after immersion in distilled water for 24 hours weight (W_1) of composite was read. This was repeated untill weight (W_1) became constant. Water absorption was then calculated in percentage in accordance with Abdul Khalil (2012).

$$\% \text{ water absorption} = \frac{Wn - Wd}{Wd} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (5.7);$$

Where: $Wn_{1,\ 2,..}$ is sample weight after and W_d is weight before immersion.

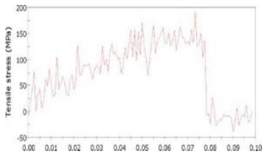
Table 5.4 presents physical properties of untreated/treated fibres of male flower bunch stalk. It showed that untreated fibres weigth, volume and density varied through the tests due to the hydrphilic and anisotropic natures of untreated materials. However after 5% NaOH treatment values were constant over 3 tests as material became more chemically and physically stable. NaOH treatment removed moisture, increased strength; enhanced flexural rigidity of fibers; cleared impurities adjoining fiber and stabilized molecular orientation. It is alkaline treatment referred to as mercerization which caused surface modification to make it wettable by matrix.

Table 5.4 Summarized result of physical properties of fibres *(Source: Ademoh and Olasoji, 2015).*

Physical property description	Untreated male flower bunch stalk fibre			Treated male flower bunch stalk fibre		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
W (g)	0.136	0.135	0.137	0.226	0.226	0.226
V_1 (mm^3)	6.00	5.90	6.10	8.00	8.00	8.00
V_2 (mm^3)	6.03	5.93	6.13	8.12	8.12	8.12
Density (X 10^{-3}Kg/cm^3)	4.53	4.50	4.57	1.88	1.88	1.88
Average Density (X-10^{-3}Kg/cm^3)	4.53			1.88		

Treatment removed lignin, hemicellulose, wax and oil covering fibre surface. Mercerization caused fibrillation that broke down fibre bundle to smaller ones, reduced diameter, increased aspect ratio and caused development of rough surface topography, gave better fibre/matrix interface adhesion that resulted to improved mechanical properties. Alkali sensitive hydroxyl (OH) group in raw fibre broke down, reacted with water and raised its structure. Remaining reactive molecule formed fibre cell-O-Na group in cellulose chains. Hydrophilic hydroxyl groups were reduced to lower certain portion of hemicellulose, lignin, pectin, wax and oil covering making fibre surfaces more homogeneous. Stress transfer between alternate cells rose for higher surface area adhesion to matrix. It raised the cellulose to stabilize material for constancy in sample values. In figures 5.26-6.29 are results of tensile stress/stain of 5 fibres. Tables 6.5-6.8 show results of length, strength, modulus, extension and stress/strain tests.

Table 5.5 Property summary of fibre tested in Fig. 5.26

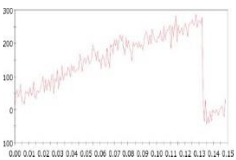


Length (mm)	Diameter (mm)	UTS (Mpa)	Modulus GPa)	Extension (mm/mm)
100.00	0.035	158.496	2.16762	0.07312

Fig. 5.26:-Stress/strain curve of treated fibre test 1. *(Source: Ademoh and Olasoji, 2015)*

In Figure 5.26 tensile strength rose with increasing strain from zero strain up to 0.73mm/mm where it reached optimum of 158.496 mPa after which it dropped. The corresponding Table 5,5 showed length (100mm) and diameter (0.035mm) of sample. Ultimate tensile strength of another fibre length (100mm) and diameter (0.95mm) in Figure 5.27 and Table 5.6 is 290mPa at strain of 0.12813mm/mm. Comparatively, Tables 5.5 and 5.6 showed ultimate strenght and modulus of same length increased with increasing diameter as a result of increaseg cellulose. FTIR, FESEM, XRD and TGA/DSC analyses on fibres and reinforcement composite always yield result that directly relate to mechanical and physical properties (Murali *et al.* 2014).

Table 5,6 Property summary of fibre tested in Fig. 2.27

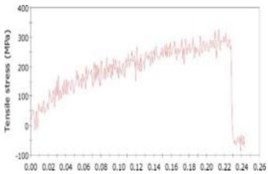


Length (mm)	Diameter (mm)	UTS (Mpa)	Modulus (GPa)	Extension (mm/mm)
100.00	0.095	290.0000	2.26333	0.12813

Fig.5.27:-Stress/strain curve of treated test 2. *(Source: Ademoh and Olasoji, 2015)*

Figures 5.26, 5.27 and 5.28 with related tables 5.6, 5.7 and 5.8 showed result of fibre of 100mm length, diameters; 0.120mm, 0.145mm and 0.170mm respectively. Fibre of same length but increasing diameter was selected to reveal property changes with varied sections.

Table 5.7: Property summary of fibre tested in Fig 5.28

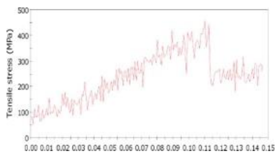


Length (mm)	Diameter (mm)	UTS (Mpa)	Modulus (GPa)	Extension (mm/mm)
100.00	0.120	320.3760	1.51756	0.21111

Fig.5.28:-Stress/strain curve of treated fibre test 3.
(Source: Ademoh and Olasoji, 2015)

Plot for each of five tested fibres was not single solid continuous curve but of wavy patterns due to anisotropic nature of biomass fibre. Graphs showed scatter plots reduced near solid with thicker curves. Material display iregular property at different points thus treatment on fibre is vital to reduce defficiency and stabilize material for easier predictivity for use.

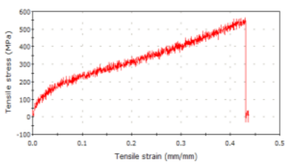
Table 5.8:Property summary of fibre tested in Fig. 5.29



Length (mm)	Diameter (mm)	UTS (Mpa)	Modulus (GPa)	Extension (mm/mm)
100.00	0.145	450.05700	4.04364	0.11130

Fig.5.29:-Stress/strain curve of treated fibre test 4. *(Source: Ademoh and Olasoji, 2015)*

Table 5.9 Property summary of fibre tested in Fig. 5.30



Length (mm)	Diameter (mm)	UTS (Mpa)	Modulus (GPa)	Extension (mm/mm)
100.00	0.170	563.49500	4.04360	0.43748

Fig.5.30:-Stress/strain curve of treated fibre test 5.
(Source: Ademoh and Olasoji, 2015)

It followed similar trend as property increased with fibre diameter. It critically affected fibre properties than length. Thicker fibre is preferred to thin one for better reinforcement/stronger composite. In Figure 5.31 are photographs of surfaces of cast helmet from fabrication mould waiting foam liner. Its external surface was smooth due to applied gel coat. Setting imparted thixotropic effect that gave it hard/smooth shiny surface. Internal surface showed roughness of laminating resin/mat. Thick viscous liquid spread after curing gel coat was set to surround fibre. The average thickness of the helmet was 4.8mm and the weight was 950g.

(a) (b) (c)

Fig.5.31:-Photographs of cast helmets awaiting foam liner; (J) External surface of helmet; (K) Internal surface of helmet before and after cleaning excess materials. *(Source: Ademoh and Olasoji, 2015)*

The weight was due to high amount of matrix that was more than reinforcement fibre. Murali et al (2014) used 40% hybrid (jute, banana sisal) and 60% epoxy binder helmet weighed 252g - 370g. Weight relates to thickness and resin matrix. Result of test on bio-mass reinforced helmets are shown below. Tensile stress/extension is curved and modulus is straigth. In figure 5.32 strength rose irregularly with extension to ultimate of 5 mPa at extension of 1.8mm.

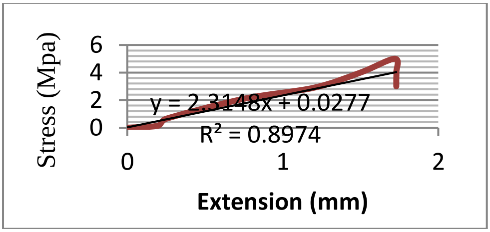


Fig.5.32: Stress vs extension of helmet (T1)

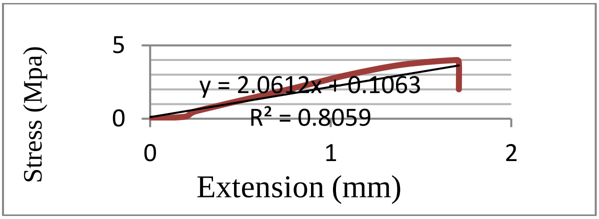


Figure 5.33: Stress vs extension of helmet (T2).
(Source: Ademoh and Olasoji, 2015)

Modulus increased linearly with extension. In figure 5.34; 5.35 stress/modulus and extension followed similar increased extension and near similar value but for irregularity in tests 2 and 3 that differ from test 1 at extention of 0.5-1.2mm and 0.8-1.2mm due to retained anisotropy of agrofibre in composite. Results in table 5.10 show they fluctuate due to the anisotropy of bio-mass fibres, values obtained are generally acceptable as compared to previous works.

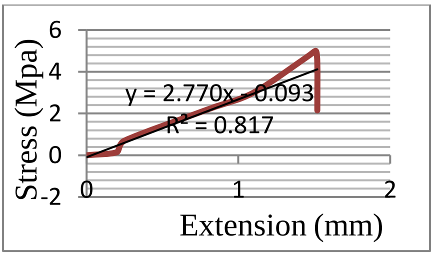


Fig.5.34: Stress/extension of helmet (test 3).

Table 5.10: Mechanical properties of helmet composite.

Test	Modulus (Gpa)	Impact (J/m)	Hardness (No)	Toughness (J)
Test 1	3.676	26.33	79	3.19
Test 2	3.164	22.33	74	3.06
Test 3	3.478	24.00	60	3.59
Avera	3.439	24.22	71	3.28

(Source: Ademoh and Olasoji, 2015)

Table 5.11 shows summary of some past works for comparison, though casting temperatures were not available. From table 5.10, impact strength of 20% oil palm composite was less than half of ABS plastic composite by Murali *et al* (2014).Compared to helmet of 10% coir/90% epoxy (Yuhazri and Dan (2007), 20% palm fibre composite gave close hardness but higher modulus. Sample weight after 24hourly immersion in water for 4 days, Table 5.12 was used to derive absorption. It decreased 24 hourly to point of no absorption from day 3.

Table 5.11: Comparison of result obtained with past literatures.
(Source: Ademoh and Olasoji, 2015)

Samples	Modulus	Impact Strength (J/m)	Hardness (No)	Toughness (J)
Yuhazri and Dan (2007);10% coir with 90% epoxy resin	8.773 mPa	9.95 J/mm^2	80.45	-
Murali et al (2014):40% hybrid jute, banana sisal fibre; 60% epoxy	-	53.06	-	-
Murali et al (2014): ABS Plastic	-	50	-	-
20% oil palm male flower bunch stalk fibre composite helmet shell	3.439 gPa	24.44	71.00	3.28

Table 5.12: Water absorption test result. *(Source: Ademoh and Olasoji, 2015)*

Description	Days of immersion in water				
	Dry weight (g)	Day 1	Day 2	Day 3	Day 4
Weight (g)	4.015	4.346	4.385	4.386	4.386
As percentage (%)	-	8.244	0.890	0.023	0.000

5.2.3 Findings and the way forward

Natural fibres have proved reliable for reinforcement of composites for heavy components. Other works done include development of asbestos free automotive brake pad using maize husk composite, fabrication of building tiles with polyethylene scrap composites; periwinkle shell and development of thermo flask lining from polymer composite reinforced with palm fibre. Thus, all three targets of green manufacturing of environmental protection; economic practice and social responsibility are satisfied. Presently 2 Ph. D researches are ongoing on use of composites for fabricating automotive engine mounts and bumpers. Of interest is an ongoing work on development of defibring machine for banana pseudostem for composites.

5.3 Lubrication Technology

Lubrication technology (tribology) is practice of placing solid, liquid or gaseous substance between surfaces that move relative to each other to prevent seizure. Most lubricants are derived from mineral non-renewable resources which after use and discharge create hazards. These can be replaced with green biomass alternatives which are more human/environmental friendly. My work on vegetable oil cutting fluid was picked to represent studies in this aspect.

5.3.1 Investigation of effective plant-based antioxidants on vegetable oil fluids/lubricants

Oils can be from two different sources, biological and non-biological. Modern technological advancement place varied demands on cutting fluid for machining thereby making selection and combination of reliable cutting fluid complex. It requires great skill and technical know-how as well as caution and sensitivity. Natural oils contain variety of substances; some hinder their lubrication ability; others improve lubrication processes. Chemicals known as additives are deliberately added to oil to improve its lubricating property. This may be done by turning, drilling, grinding and facing e. t. c. Each of these processes involves heat generation that can be detrimental to both the cutting tool and work piece. Hence the need to use cutting fluids to cool work piece, tool, also alleviate extreme pressure on tool and work piece. Additives are not restricted to chemicals alone. They can be food substances that contain chemical elements that influence oils and drastically alter properties of cutting fluid vital to overall performance.

Additives are added for specific purposes like anti-aging, oxidation/corrosion inhibitors, anti-wear, dispersant, emulsifier, biocide, extreme pressure effects and other reasons (Brinksmeier *et al.* 2015). In a study, Didam (2014) investigated five vegetable oil including jatropha. Each oil reduced cutting temperature and improved surface finish for mild steel turning operation at varied spindle speed, feed rate and depth of cut as compared to when it was cut dry. Result showed oil is suitable cutting fluid with high cutting temperature. Studies on physicochemical properties indicated they need modification with additives for good performance. Properties affecting cutting temperature and surface roughness are flash/pour point, kinematic viscosity, thermal conductivity and specific gravity. Each is affected by additive on oil and is advisable to use friendly rather than mineral additives. Additives which produce required improvement must be those that serve as anti-oxidant to prevent free fatty acid (FFA) in oil from oxidizing and emitting heat. To reduce oxidation of FFA addition of substances containing sulphur, phosphorus, chlorine or boron is required as they act as excellent anti-oxidants. With desire to produce effective cutting fluid from readily available materials, study into substances with high sulphur was done. Garlic and tobacco topped list of food with sulphur and chlorine. This motivated choice of the additives in this work to replace mineral non renewable substances.

5.3.2 Use of tobacco and garlic as antioxidants in vegetable oil cutting fluid

Determination of quantities of additives to be used:-It was decided that one litre of oil was to be used per time after considering coolant flow rate (80 ml/hour). At cutting speed, length of mild-steel bar work piece was dry machined in less than 30 minutes. Next was percentage of additive in quantity by weight. Considering that additives were selected based on sulphur in combined state as sulphate, their quantity was substantial. By reference to Erna *et al* (2013) additive in pure forms were made at 500 ppm (0.5 mg), 1000 ppm (1.0 mg) and 1500 ppm (1.5 mg) to 50 ml oil. Based on this it was desired to have average of 100 mg/l added to oil. Thus average of 5g/l of tobacco and 4.2 g/l of garlic was used. The compound that was active in amount larger than sulphates that affect property of oil was chloride. Other elements were negligible and not capable to influence properties. Brinksmeier *et al* (2015) said effectiveness of oil based cutting fluid was enhanced by adding materials that contain chlorine, boron, sulphur or phosphorus. Additives were computed as weight (%) of 1 litre oil as in Table 5.13:

One litre jathropha oil = 1600g; thus, quantity of additive made to 1 litre jathropha oil was:

For 0.05% additive = $\frac{0.05}{100} \times 1600 = 0.8g$; For 0.15% additive $= \frac{0.15}{100} \times 1600 = 2.4g$.

For 0.25% additive $= \frac{0.25}{100} \times 1600 = 4.0g$; For 0.35% additive = $\frac{0.35}{100} \times 1600 = 5.6g$.

And for 0.45% additive = $\frac{0.45}{100} \times 1600 = 7.2g$. (Ademoh and Omole, 2017)

Table 5.13:Amounts (grams) of additives made jatropha oil *(Ademoh and Omole, 2017)*

Additives-Garlic or Tobacco (%)	Additives -Garlic or Tobacco (g)
0.05	0.8
0.15	2.4
0.25	4.0
0.35	5.6
0.45	7.2

Analysis of additives:-In determining sulphate and chloride contents in garlic and tobacco, titrimetic method was used. Analysis was absolute as substance concentration is known from fundamental chemistry. Calcium, potassium/magnesium were measured by atomic absorption spectroscopy (AAS), that deals with recording absorption of light by vapourized ground state atom and link it to concentration was used as stated in Beer's law (Skoog, 2007). The 2 steps in the process are atomization of sample and absorption of radiated light. Determination of oil/moisture was by proximate analysis. Samples were grouped and fed in five on chemical properties as moisture, ash, crude protein and lipid/nitrogen-free extract. Four samples were obtained experimentally while the fifth was computed and added up to 100%.

Property tests:- Jatropha oil was obtained from NARICT Zaria. Ground garlic and tobacco of varied percentages were added to samples separately. Physicochemical test of oil with garlic, tobacco and sample with no additives were done. Kinematic viscosity was tested with cannon fenke capillary viscometer. Capillary was placed vertically in transparent viscometer water-bath maintained at 35°C and allowed to stand for a while for its temperature to be uniform with water-bath. On the capillary were 2 marks. Automatic pipette filler was used to fill oil to upper mark. Stopwatch was used for the timing. Thermal conductivity was tested with hot-wire principle based on temperature rise at a point from heat source having constant/uniform out-put. Flash point was tested by exposing heated sample to open flame crucible housing sample (ASTM D92-16b). Jatropha, garlic and tobacco used are in Figure 5.35. Open flame was made at interval to sample surface and kept until temperature rose close to flash point.

Fig.5.35a:-Jatropha oil/seed.

Fig.5.35b:-Powdered garlic.

Fig.5.35c:-Powdered tobacco leaf

(Ademoh and Omole, 2017)

Pour point was determined when frozen sample started to pour (ASTM D97). Sample was cooled to freeze in refrigerator, removed and exposed to warm air in room. Temperature gradually increased, the beaker containing sample was tilted to make it easy to observe flow. It was taken immediately flow was noticed. Specific gravity was conducted with pycnometer. Empty pycnometer was first weighed, noted as W, filled with sample and reweighed as W_1. Test was done and pycnometer containing same volume of water was reweighed as W_2.

Work piece was mounted on EXCEL lathe and secured with chuck key. A high speed steel cutting tool was mounted on tool holder after grinding to right clearance and rake angle. Tool bit was ground with sharp angle to ensure facing to edge of center. Tool post was adjusted to be perpendicular to work piece, speed selector turned to 355 rpm and feed to 0.262mm/rev. IR-66 infrared thermometer was held close to read temperature of cutting. Spindle speed/feed rate were maintained for all machining operations; depth of cut of 0.50mm was taken at each time. Dry machining was done followed by cutting with plain oil. Jatropha oil with varied percentages of garlic and tobacco were then used for machining. Additive was mixed in oil with magnetic stirrer. Temperature was read 3 times to arrive at the averages in Table 5.14.

Surface Roughness Test Measurement:-Steel sample were machined on XL400 EXCEL lathe machine and surface roughness indices were determined with a CVR-135 surface roughness tester. It was allowed to and fro on turned surface to read roughness and the average taken.

Table 5.14: Experimental details used for machining operation *(Ademoh and Omole, 2017)*

Experimental details/Process param	Values
Work specimen Material Size	AISI 1020 (C=0.16-0.25%,Mn=0.6-8%,Ti=0.2=0.3) Ø40mm×150mm
Cutting velocity Feed rate Depth of cut Coolant flow rate	5.604 m/min 0.262 mm/rev 0.5mm 80ml/hr
Machine tool: Lathe machine Spindle speed Cutting tool	XL400- Excel 355 rpm High speed steel

Presented in Tables 5.15 and 5.16 are compositions of the experimental raw materials: tobacco, garlic and jatropha base oil used. Brinksmeier et al (2015) said oil performance is aided by addition of substances bearing sulphur, phosphorus, chlorine and/or boron. In table 5.15 garlic/tobacco has sulphur and chlorine in forms of sulphate and chloride.

Table 5.15:Constituents of powdered additive

S/N	Elements	Tobacco	Garlic
1	Sulphate (mg/L)	20	24
2	Chloride (mg/L)	58.4	38.9
3	Calcium (ppm)	5.7796	0.9579
4	Potassium (ppm)	1.8471	2.2601
5	Magnesium (ppm)	0.9576	0.8693
6	Crude lipid (%)	8.17	1.50
7	Moisture (%)	3.30	9.90

Table 5.16:Analysis of Jatropha oil.

S/N	Property	Value
1	Specific gravity	0.9284
2	Flash point (°C)	121
3	Pour point (°C)	-6
4	Kinematic Viscosity 100°C	7.76
5	PH value	5.4
6	FFA (as % oleic acid)	2.31

(Ademoh and Omole, 2017)

Presence of free fatty acid (FFA) aided exothermic oxidation emitting more heat. Figure 5.36 and 5.37 present result of garlic and tobacco on oil viscosity. As garlic increased steady fall showed thinner oil film. Particles interfered with ability of fluid molecules to bond together leading to low viscosity as the quantity of solid in oil affected its circulation rate. A deliberate act was taken to ensure more particle circulation. Sulphur and chlorine acted as antioxidants. Added tobacco raised kinematic viscosity before drooping due to lower density. Instead of serving as heavy particle obstructing fluid bond it acted as nano-particle to raise viscosity.

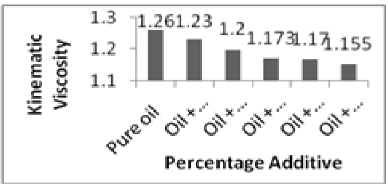


Fig. 5.36:-Effect of garlic on kinematic Viscosity of Jatropha oil

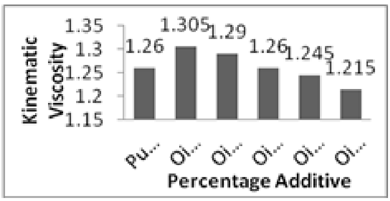


Fig.5.37:-Effect of tobacco on kinematic Viscosity of Jatropha oil

(Ademoh and Omole, 2017)

Viscosity of nanofluid improved from 2.62-4.82% of base oil. Compared to garlic in jatropha, it showed subsequent reduction in viscosity with low tobacco due to less tobacco density. The critical Weber number of penetration was modeled as function of contact angle, particle size, ratio of particle density to that of liquid showed solid particle density increased penetration number and viscosity. Figure 5.38 shows effect of garlic/tobacco on thermal conductivity of jatropha. Singh (2008) didn't just establish that particles in fluid raised thermal conductivity, but gave reasons for Brownain motion of particle, molecular level layering at liquid/particle interface, nature of heat transport in particle and clustering effect in fluid have been found to cause this. Aggregation/development of long particle structures was responsible.

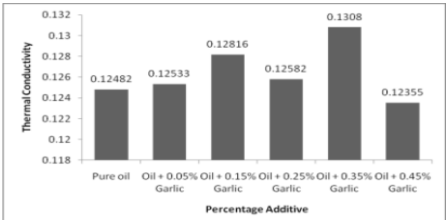


Fig 5.38:-Effect of garlic on thermal conductivity of jatropha oil.

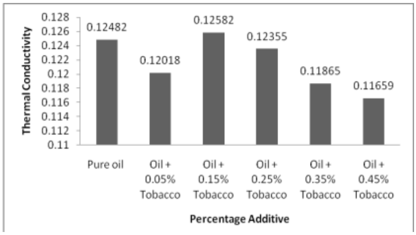


Fig 5.39:-Effect of tobacco on thermal Conductivity of jatropha oil.

(Ademoh and Omole, 2017)

Its adverse effect proved conductivity increased with increased mass fraction of particles and that mass fraction was more vital than amount of particles. The particles showed that unlike garlic, tobacco was of lower density. It made difficult to affect fluid as it floated instead of penetrating making molecular level layering at liquid-particle interface insignificant due to few liquid-particle interfaces. Bruce and Joseph (2012) said conductivity is linear function of bulk density, thus tobacco lost its conductivity. Figure 5.40 and 5.41 present results of effects of garlic/tobacco additions to flash point of jatropha. It reduced flash temperatures. Sulphur in oil from additives reduced flash point. Report by MAN Diesel (2017) on low-sulphur fuels stated that increased sulphur caused lowering in flash point. Possible reason for fluctuation with increased added garlic was water in oil as moisture in garlic is high. Water prevented oil vapour from flashing and raised it. Another reason for decline was the presence of tobacco particle that increased fluid and lowered flash point as they burn off at lower temperature.

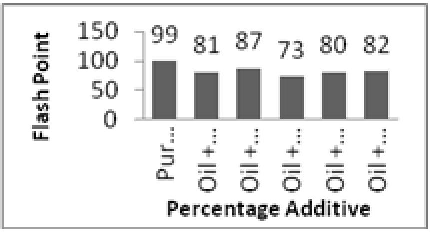


Fig.5.40: Effect of garlic addition on flash point of jatropha oil

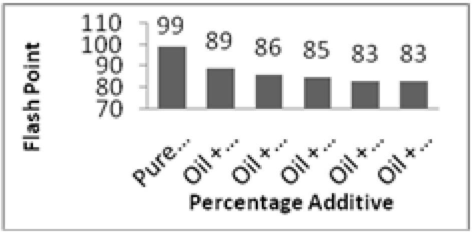
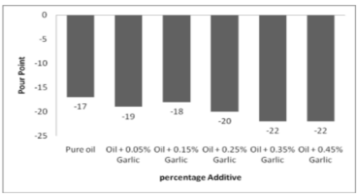


Fig.5.41: Effect of tobacco addition on flash point of jatropha oil

(Ademoh and Omole, 2017)

Figure 5.42 and 5.43 show effects of garlic/tobacco on pour point. Afton chemical (2017) stated that pour point depressants are liquid or solid substances that assist base oil become active at lower temperature and keep viscosity at high temperature. Evonik Industries (2017) stated that depressant is partially dependent on molecular weight and when oil crystallizes, particles crystallize along and change growth pattern of wax crystal structure. 3-dimensional structures inhibiting flow were prevented from forming wax crystals due to steric hindrance brought of particles that keept oil crystal apart. Wax inhibitors had more effect on pour point and apparent viscosity than temperature. With garlic in jatropha pour point reduced as more of it lower value making it excellent depressant. Tobacco had some alkyl groups of PPD prevented growth of 3-dimensional structure that inhibited oil flow (Evonik Industries, 2017).



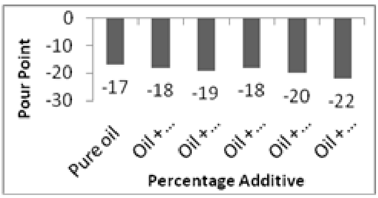


Fig.5.42:Effect of garlic on pour point of oil

Fig.5.43:Effect of tobacco on pour point of oil.

(Ademoh and Omole, 2017)

Garlic declined by 2°C and tobacco by 1°C. Density of garlic was higher than tobacco. High molecular weight contributed to PPD. In Figures 5.44 and 5.45specific gravity increased due to higher weight that is a function of density. Difference being that density refers to mass per unit volume of substance while specific gravity refers to substance in relation to a standard substance (water). In Figure 6.44 there was increase in specific gravity as additive increased. However it increased by 0.002 with every increase in garlic and 0.001with tobacco in oil.

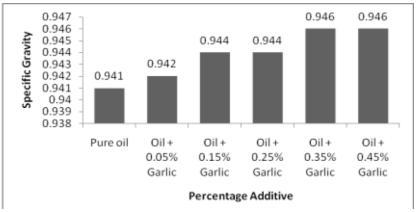


Fig.5.44:Effect of garlic addition specific gravity of jatropha oil

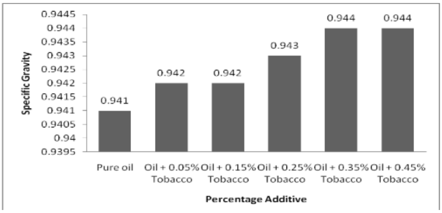


Fig.5.45:Effect of tobacco addition specific gravity of jatropha oil

(Ademoh and Omole, 2017)

This indicated that density of garlic was higher than tobacco. Density of garlic is 570 kg/m^3 and tobacco is 320 kg/m^3. Figure 5.46 and 5.47 show machining process with cutting fluids.

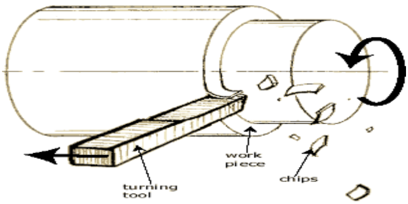


Fig. 5.46:Cutting operation

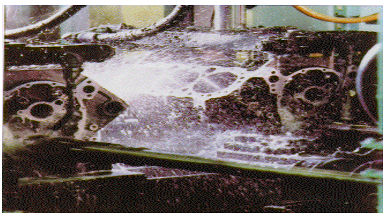


Fig. 5.47:Splash machining with cutting fluid.

(Ademoh and Omole, 2017)

Average temperature with garlic in jathropha oil cutting fluid is shown in Figure 5.48. Figure 5.49 shows the surface roughness of samples. Wide difference in result from dry machining and the result from 44.03°C-32.83°C showed jatropha oil can serve as coolant in machinnig. Temperature of machining with pure oil was high as high viscosity inhibited ability cooling.

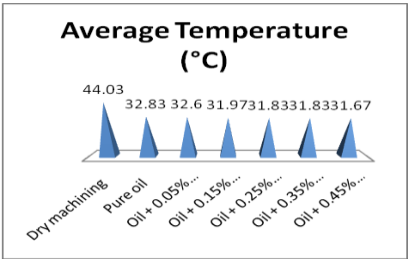


Fig.5.48:-Cutting temperatures of specimens machined with garlic added to jatropha oil

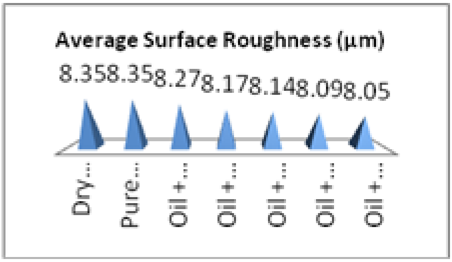


Fig.5.49:-Average surface roughness of samples machined with garlic in jatropha oil

(Ademoh and Omole, 2017)

Viscosity is attribute of fluid that inhibits relative motion of surfaces of fluid. Jatropha oil high viscosity must be reduced by added garlic to use it as coolant/engine oil. In Figure 5.49 is surface roughness of samples machined with garlic in jatropha. Compared with machined dry and machined with pure oil are same-8.35µm due inactivity of oil. Cutting oils are classified as active or in-active. Active oil has added sulphur while inactive oil has no sulphur but naturally occurring sulphur with strong bond and are seldom released to function in fluid. When sulphur broke out of bond it reacted with machined surface to create better surface finish. However added 0.05% garlic gave better surface of 8.27µm; better results are obtained with higher values. Sulphur antioxidant reacted better with metal (Joachim et al 2013).

<u>Machining with tobacco in Jatropha oil cutting fluid</u>**:-**Temperature obtained when jatropha oil with tobacco additive used for machining are as in figure 5.50; surface roughness in Figure 5.51. Unlike garlic in jatropha that instantly decreased temperature, tobacco showed initial temperature rise as it burnt due to its lower density and altered combustion rate. It also compacted material and made it difficult for heat to penetrate (Ademoh and Omole, 2017).

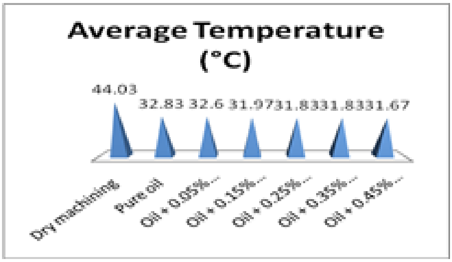


Fig.5.50:Cutting temperatures of specimens machined with tobacco added jatropha oil

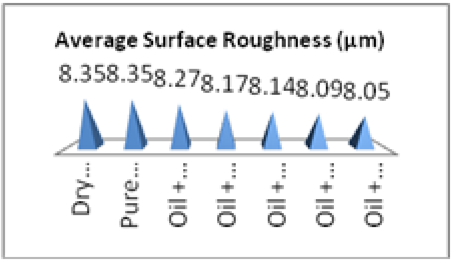


Fig.5.51:Average surface roughness of samples machined with tobacco in jatropha oil.

(Ademoh and Omole, 2017)

Tobacco particles moved along with oil. Some got burnt in short exposure to machining heat. Tobacco had incomplete combustion due to insufficient oxygen. Water and heat are products of complete combustion. Incomplete combustion produced carbon dioxide, carbon monoxide and carbon (Ademoh and Omole, 2017). Heat generated was reason for rise in temperature in pure oil machined sample to 0.5% tobacco. As amount of tobacco increased so did release of water as coolant and temperature drop. In Figure 5.51 surface finish rose with tobacco as burnt carbon soot deposit acted as layers sliding over each other to lubricate process. More tobacco released sulphur oil to interact with metal thioester linkages to give finer surface.

5.3.3 Findings and the way forward

Tobacco leaves and garlic have been shown to be active antioxidants when added to jatropha seed oil for metal machining operation as they generally enhanced the tribological properties of vegetable oil. They gave similar results as neem and castor oils in different studies. Thus, all three targets of green manufacturing of environmental protection; economic practice and social responsibility are satisfied. Based on these studies, Ph. D research on development of synthetic power turbine oil from some plants and bio based additives work on automotive synthetic automotive engine oil from vegetable based oil and additives are also ongoing.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

In this lecture acacia species sourced from organic plants have been shown to be effective binder in metal manufacturing industries serving as alternative/replacement for nonrenewable corrosive synthetic binders. It revealed potential use of natural fibre sourced from different parts of oil palm tree/fruit to reinforce composites for engineering components of properties comparable to/better than synthetic nonrenewable fibre. Ease of sustainability, disposability after use, environmental/human friendliness agrees with green manufacturing goals. Tobacco and garlic have proved to be effective antioxidants in vegetable oils for lubricant applications as replacement for mineral nonrenewable oils and thus satisfy aims of green manufacturing.

Massive investment in plants and trees do not only raise economies of farmers and generate wealth but help to rejuvenate environment as they take up the green house gasses generated from manufacturing giving out oxygen and ease the problem of climate change and global warming. The potential of Africa to develop through alternative manufacturing processes that are effective and environmentally friendly are great due to her massive bio-resources, ease of treating or disposing the wastes which are readily bio-degenerable and renewable. These are the goals of green manufacturing that very much give economic benefits like lower material costs, decreased overhead expenses, increased employee morale, reduced downtime, wealth and create job opportunities that are so much needed in Africa. What is needed is the zeal and determination to formulate articulate industrial policies with dedicated implementation plans.

7.2 Recommendations

With the massive agro resources that abound in the continent, Africa can occupy her space in global affairs through use of low cost, intermediate and appropriate technology. All of which aggregate into what is referred to in this lecture as green manufacturing. Low cost technology is the deployment of simple techniques to produce goods at small/medium scales which can diversify an economy into outfits inter-related aggregating to very industries. In this way raw materials are sourced from renewable agro-products, presently wasted or exported without value additions. Wastes from such are bio-degenerable or serve as recyclable raw materials in other industries/sectors. When speaking of low cost technology, one is focusing primarily on economic dimensions of intelligent innovations to fast track productivity of nations.

Intermediate technology is the use of techniques higher than low cost technologies to produce goods using locally developed processes and machines. Appropriate technology refers to use of available resources to generate needs of society. Low-cost, intermediate and appropriate technologies generally refer to methods developed/imported and used by developing nations.

The concept of appropriate technology on the other hand belongs specifically to the field of engineering which tends today, to be somewhat more popular than low cost or intermediate technology. It represents what one may call socio-cultural dimension of innovation. The idea is that the value of new technology lies not only in its economic viability/technical soundness but on its adaptation to socio-cultural environment. Assessing appropriateness of technology necessarily implies some value judgment both on the part of those who develop and use it. If ideological considerations come to play as often, appropriateness is at best, a fluctuating concept. Most of the terminologies are however, equally relevant to highly industrialized countries and are in many ways rather similar to soft or alternative technologies

Soft or alternative technology movements all emphasize the need for much greater attention to ecological impact of new techniques and to real needs of society. All these aspects of green manufacturing can address main targets of sustainable raw material sources, recycling and bio-degenerable industrial wastes suited to urban and rural environments that are typical of African settlements. Efforts must be geared towards exploring new paths in non-polluting agro-technology and use of renewable resources such as wind, solar, tidal and other energy methods of conservation tools and technology for full deployment of green manufacturing processes to build Africa. These are the easiest and quickest approaches that Africa can adopt to catch up with the rapid industrialization of the world so as not to be left behind.

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9.0 PERSONAL PROFILE OF THE INAUGURAL LECTURER

Engr. Prof. Nuhu Ali Ademoh is a Professor of Mechanical Engineering with specialization in design and production engineering option, Department of Mechanical Engineering, School of Infrastructure, Process Engineering and Technology, Federal University of Technology, Minna. He was born 24th June, 1965 at Adavi-Odu, Adavi Local Government Area of Kogi State. He had his primary education at St. Paul's Primary School, Adavi Eba, Adavi Local Government Area of Kogi State from 1973 - 1978. His secondary education was at Federal Government College, Kaduna from 1978 to 1983. While at FGC, Kaduna he emerged the overall second best student in his set and was awarded Federal Government merit scholarship from form two to five. In a vision to be part of core engineers who will see to development of Ajaokuta Steel Company into success, he thereafter enrolled and obtained his first degree in Metallurgical and Materials Engineering in 1988 at Obafemi Awolowo University, Ile-Ife in Oshun State where he graduated with Second Class Upper Division. On completion of the National Youth Service Corps at Enugu in Anambra State in 1989, he proceeded immediately to University of Lagos where he obtained M. Sc degree in Mechanical Engineering (Design and Production) in 1991.

His love for academics made him start lecturing at Bayero University, Kano in 1992-1994. He was engaged as consultant engineer in an engineering company, Technokonsult Ltd, Kano (1993-2000) where he worked as a consultant engineer to Federal/State government projects that included plant audit of Jebba Paper Mill, Kwara State; Resident Engineer at Iwopin Pulp and Paper Mill reactivation at Ijebu water side, Ogun State; Project Consultant to Petroleum Trust Fund for rehabilitation of Federal Polytechnics in North West Nigeria and national farm power machinery rehabilitation. He was Deputy Managing Director of Basic Tech Industry (1995-1996), the biggest foundry (spare part production for textiles) in northern Nigeria.

He went back to lecturing at Nigerian Defence Academy, Kaduna in 1996-2010. At Nigerian Defence Academy, he was Head of Department of Mechanical Engineering in 2004-2006 and was the pioneer coordinator of Cadets Industrial Works Experience Scheme in 1997-2000. In order to improve his academic and managerial abilities he enrolled and got his Postgraduate Diploma in Management at Abubakar Tafawa Balewa University, Bauchi in 2002. In order to to consolidate on his academic career he secured admission at Bayero University Kano and obtained PhD Degree in Production Engineering option of Mechanical Engineering in 2009. For diversification of his work experience, he transferred his service from Nigerian Defence Academy, Kaduna to Federal University of Technology, Minna in 2010. He has supervised numerous undergraduate, masters and Ph. D degree theses in well articulated topics. He has contributed immensely to scholarly works in different areas of mechanical engineering majoring as reviewer to international and local journals in design, production, heat treatment, nano particles studies and engineering composite development.

He has published more than 60 research articles in series of reputable Nigerian, international journals and conferences. He has served in many committees at Nigerian Derfence Academy and some at Federal University, Minna. He has participated in many community development services. These include Ebira Group for Advancement Initiative, an educational counseling and endowment group, Kogi Central where he was Vice Chairman; member of National Board for Technical Education panels for resource verification and accreditation to several federal/state polytechnics and National Universities Commission as member for accreditation and resource verification panels. He also served as assistant chief examiner for Council for Regulation of Engineering in Nigeria in professional examinations for registering new engineers. Furthermore he has served as external examiner to polytechnics and universities. He was promoted to Professor in October, 2015. He is married and blessed with children.

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